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NEEDLE DAMS FOR RIVER IMPROVEMENT

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This is to certify that the thesis of CHIH HSU entitled NEEDLE DAMS FOR RIVER IMPROVEMENT was prepared under my personal supervision; and I recommend that it be approved as meeting this part of the requirements for the degree of Bachelor of Science in Civil Engineering.

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NEEDLE DAMS for RIVER IMPROVEMENT.

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INTRODUCTION.

The solution of the problem of improving rivers of moderate flow can be attained most satisfactorily by the construction of high-lift movable dams. The purpose of movable dams is to conserve the water in a stream during the season of medium flow, so that navigation may go on uninterruptedly through the lock, and restore the stream to its natural condition again (by lowering the dams) upon the approach of sufficient water for free navigation.

Movable dams may be divided into two general classes:
(1) those requiring extraneous power for their maneuvers, and
(2) those operated by the force of water properly applied.
Among the first class may be named the various types of trestle and wicket dam, like the Poirée, Chanione, Boulé, Caméré, etc., while the second class comprises the several forms of bear-trap, drum-wickets, etc., The first class is practically the only one so far applied to navigable rivers, and its application has been confined largely to the wicket of Chanione and the trestle and needle of Poirée. In this thesis only the Poirée type will be taken into consideration.

The development of the Poirée dam in France and Belgium since its invention will be the history of that dam. It has undergone some modifications. As the parts have increased in size, they have become complex and more difficult to handle. In the first dam, erected at Basseville, the trestles were 6.56 feet apart, but this number was soon doubled; they were 4.92 feet high and 3.28 feet wide at the base. They operated with perfect success. The Decize

dam, built in 1836, was 328 feet long. The trestles were 6.23 feet high, 3.28 feet apart. In the Epinean dam, in the Yonne, erected in 1837, the trestles were 6.5 feet high and 3.28 feet apart; the sill being 1.28 feet below low-water mark. The fixed weir was 463 feet long, the pass being 229.6 feet long. The Marne dam (1841) was 6.69 feet high as to the trestles. The sill was 2.62 feet below low water, the weir was 1416 feet long, and the pass 158.42 feet long. The Yonne dams erected from 1838 to 1842, had trestles from 7.5 to 7.38 feet high. The Courbeton dam (1849), had a pass 123 feet wide. The trestles were 8.o3 feet high and weighed 371 lbs. each. This tendency to increase the height of trestles has gone on constantly until a height of 13.12 feet was reached in the Meuse dam, and 15.2 feet in the Louisa dam, the first American needle dam.

As the Louisa dam sustains a greater head of water than any dam of the same type previously built and, what is of greater importance, since its very successful operation with this unprecedented head gives promise that movable dams, if properly designed, can be built and operated with still greater lifts at a cost which is not exorbitant compared with that of fixed dams when we take into account the obvious advantages of the movable structure for securing slack water navigation, it is worth while to be investigated and discussed here in considerable detail. For the investigation the "Report of the U.S. War Department", part 3,1897, will be referred to. In this report details and informations regarding the superstructure and substructure of the dam can be found.

POIREE NEEDLE DAM,

On the Big Sandy River, at Louisa, Ky.

This dam was completed and opened for public use Jan. 1st., 1897, and has been in successful operation throughout the past years. Its design is a radical departure from that of European dams in many particulars. The needles are very much wider and heavier, the style of trestle much lighter, and its construction much cheaper, and the methods of operation of both trestles and needles are entirely new. Many new features of minor importance were introduced in the design, most of which were for the purpose of simplifying the maneuvers. The works consist of (1) a lock on the right, or Virginia bank, 52 feet wide and 225 feet long over all; (2) a navigation pass next the lock 130 feet long, having a depth of 13 feet of water on its sill; and (3) a weir 130 feet long separated from the pass by a masonry pier 12 feet wide and terminating in an abutment 17.5 feet wide on the left, or Kentucky bank. The weir has a depth of 7feet of water on its sill. The object of the weir is to provide a means for passing small rises without having to handle the heavy appliances of the pass. When the flood has reached the full discharge capacity of the weir, and is still rising, the pass must be lowered.

In the investigation of the dam the following specifications will be referred to.

Unit Stresses (lbs. per sq. in.)

Axial tension on net section.....................16,000

Axial compression on gross section....... ....$16{,}000 - 70\frac{l}{r}$

where "l" is the length of member in in.
and "r" is the least radius of gyration in in.

Impact to be added to live-load stresses.......100%

Shearing: shop driven rivets and pins....... ..12,000

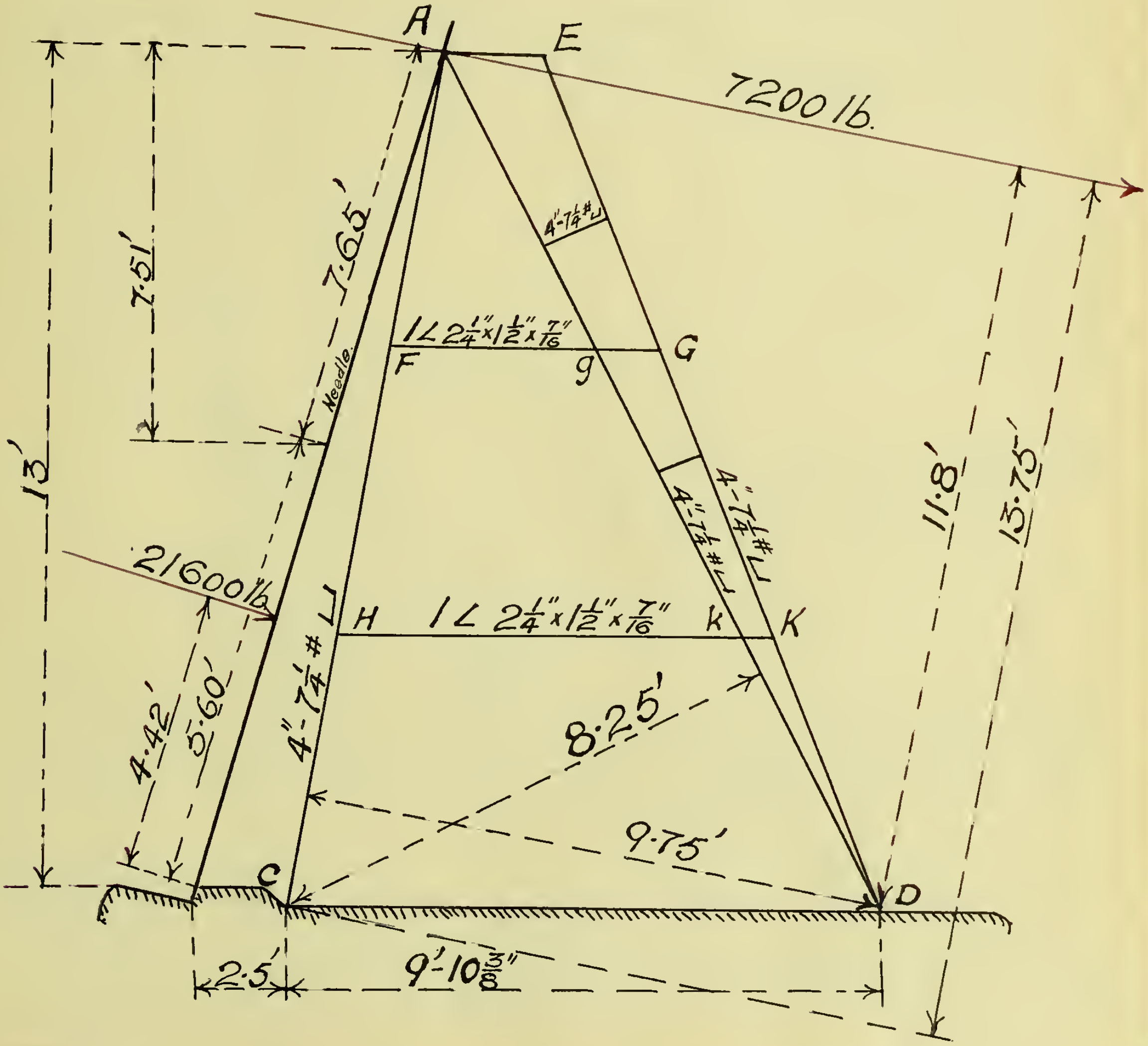
Bearing: shop driven rivets and pins...........24,000

Needles:

The needles, both for the pass and for the weir, are made of white pine, 12 in. wide. The former are about 14 ft. long, 8.5 in. thick at the bottom and 4.5 in. at the top, being designed for a stress of 1200 lbs. per sq. in.; the latter are about 8 ft. long, 3.5 in. thick at the bottom and 2.5 in. thick at the top.

Pass Needles:

fig 1.



Pressure on 1 needle $= 62.5 \times \frac{13}{2} \times 13.25$

$= 5400$ lbs., of which one-third goes

to the escape bar and two-thirds to the sill; therefore the max. shear occurs in the bottom of the needle near the sill and is equal to $\frac{2}{3}$ of 5400 lbs. i.e. 3600 lbs.

Unit shear $= 3600 \div (8.5 \times 12)$

$= 35.3$ lbs. per sq. in.

Taking 75 lbs. per sq. in. as allowable shearing stress,

Efficiency of needle is, $\frac{75}{35.3}$, 213 %.

The max. moment under these conditions occurs at a vertical distance, $d = \frac{h}{\sqrt{3}}$, from the surface, if h is the depth of the water, or in this case is equal to 13'; therefore d = 7.51';

and the corresponding distance along the needle is 7.65'.

Max. Moment $= (1800 \times 7.65 \times 12) - (1 \times 7.65 \times 62.5 \times \frac{7.51}{2} \times \frac{7.65}{3} \times 12)$

$= 110{,}000$ lb - in.

Then from the usual formula,

$$I = \frac{Mt}{S2} = \frac{bt^3}{12}$$

$$\frac{M}{S} = \frac{bt^2}{6}$$

$$S = \frac{6M}{bt^2},$$ the extreme fibre stress.

$$S = \frac{6 \times 110{,}000}{12 \times 6.8 \times 6.8};$$ 6.8" being the thickness of needle at the point 7.65' from water surface,

$= 1190$ lbs. per sq. in.

Efficiency $= 100$ % say, $\left(\frac{1200}{1190}\right)$.

This somewhat high stress was adopted in order to reduce the size of the needles as far as practicable and to handle them with less difficulty.

According to " Cambria " the average ultimate breaking unit stress of white pine is 7000 lbs. per sq. in. The factor of safety

then is 5.83, (7occ ÷ 12oo), for dry timber, but generally timber which has absorbed water in amount equal to one - half of its dry weight has a strength only about one-half that of dry timber; hence the factor of safety is reduced to about 2.91. Usually a factor of safety of 6 is taken for ordinary work to cover the variation of stresses, quality of timber etc. Therefore the timber used for needles must be free of knots and other defects.

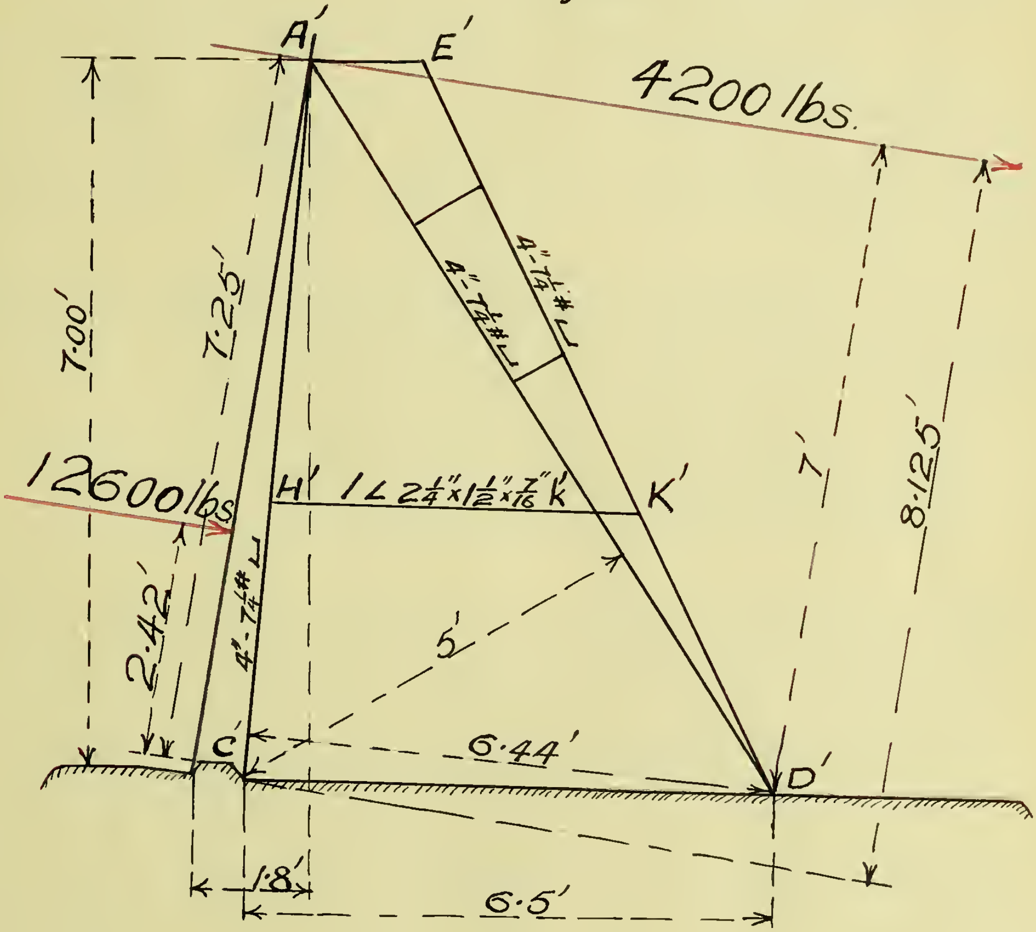
$$\text{Weight of one needle} = \frac{1 \times 8.5 \times 4.5 \times 14 \times 23.75}{2 \times 12}$$

$$= 18o \text{ lbs. when it is dry,}$$

but when it absorbs water it may weigh as much as 27o lbs.

Weir Needles:

fig 2.



Pressure on 1 needle $= 62.5 \times \frac{7}{2} \times 7.25$

$= 1575$ lbs.,

$\frac{2}{3}$ of which $= 1050$ lbs. goes to the sill,

and $\frac{1}{3}$ of which $= 525$ lbs. goes to the escape bar.

Unit shear, $\frac{1050}{3.5 \times 12}$, $= 25$ lbs. at the bottom of needle.

Efficiency, $\frac{75}{25}$, $= 300$ % for shearing.

d, $\frac{7}{3}$, $= 4.04'$

and the corresponding distance along the needle is 4.18'.

Max. Moment $= (525 \times 4.18 \times 12) - (4.18 \times 62.5 \times \frac{4.04}{2} \times \frac{4.18}{3} \times 12)$

$= 17580$ lb-in.

$$S = \frac{6 \times 17580}{12 \times 3.078 \times 3.078}, \text{ as } 2.5 + \frac{4.18}{7.25} = 3.078,$$

$= 930$ lbs. per sq. in.

which was assumed to design the needles as they are more liable to deterioration from frequent handling.

Safety factor, $\frac{7000}{930}$, is 7.5 which is fairly great for ordinary work, but not in this case, because $\frac{1}{2}$ of 7.5 is only 3.75.

Weight of 1 needle $= \frac{(3.5 + 2.5) \times 1 \times 8 \times 23.75}{2 \times 12}$

where 8' is the total length of needle.

$= 47.5$ lbs. when it is dry,

or $= 71.3$ lbs. when it absorbs water.

Owing to the great difference of weights between the pass needles and the weir needles, the facility of maneuvering them thereby differs. The weir needles can be placed and removed by hand, and if any have to be put in under a full head, as in regulating, their tops are held against the escape bars and the ends plunged up stream in the current which draws them round till they

stike the sill. The pass needles are placed by a derrick-boat, and can be put in without great difficulty with a head of 3 or 4 feet. The removal of the needles is affected by attaching the up-stream side of each one to a chain, allowing about 2 feet of slack between, and then pulling it from the boat, which is moored about 1oo feet above the dam. By this means all the weir needles can be removed under a full head in a very short time.

As regards to the kind of timber, white pine appears to be the most satisfactory, as it possesses the greatest strength, weight for weight, and does not splinter easily. Oregon pine may probably make an excellent needle also. Needles of wide face are much preferable to narrow ones, as there are fewer joints and less tendency to warping, thus securing a minimum of leakage.

The leakage through the pass when the pool is at normal height, 13' above sill, with no down-stream pressure = 2o.5' X o.6 = 12.3 ft. per sec, (determined by using the Chanione formula). Area of opening with needles $\frac{1}{8}$ in. apart = 13 ft 3.5 in. X $\frac{1}{8}$ = o.138 sq. ft. Hence leakage per needle i.e. per ft. = 12.3 X o.138 sq. ft. = 1.7 cu. ft. per sec. Total leakage between pass needles = 222 cu. ft. per sec. The weir leakage amounts to 121 cu. ft. per sec. by the same formula. In the sides of the pass needles a shallow groove is cut which will hold a strip of rubber should it become desirable to restrict the leakage. By this means the leakage can be reduced to almost nothing.

NEEDLE DAM, BIG SANDY RIVER,

WEST VIRGINIA AND KENTUCKY .

View of the weir , showing the last trestles being raised six at a time.
The other trestles are all up and several bays of needles in place.

View of the weir trestles all fitted and in place. The ends of the escape bars are seen projecting on the left below the floors. The tops of the floors are about 2 inches below the top of the sill.

View of pass trestles and needles.

Trestles:

The pass is closed by 31 and the weir by 34 steel trestles. The pass trestles are 4 ft. apart, and each leg is composed of one 4-in 7.25-lb channel. On the weir the trestles were made of similar section and outlines and are used to carry a span of 8 ft.

Pass Trestle: (see fig. 1)

Pressure on top of trestle $= 4 \times 1800 = 7200$ lbs.

Tensile stress in upstream post, AC, $= \dfrac{7200 \times 11.8}{9.75}$

$= 8,800$ lbs.

Compressive stress in downstream post which is made of two pieces, AD and ED, $= \dfrac{7200 \times 13.75}{8.25} = 12,000$ lbs., one-half of which goes to DE and the other half to AD because AD and DE are rigidly braced together.

Net section of AC $= 2.13 - (0.33 \times 2 \times \frac{5}{8})$

$= 1.72$ sq. in. (2 rows of $\frac{5}{8}$" rivets)

Tension in AC $= 5100$ lbs. per sq. in. $\left(\dfrac{8800}{1.72}\right)$

Factor of safety $= \dfrac{60000}{5100 \times 2}$, where 6000 being ultimate strength of medium steel, lbs. per sq. in. and 5100 lbs. provided for impact.

$= 5.9$

Efficiency $= \dfrac{16000}{10200}$

$= 157\ \%$

But 500 lbs. acting down AC due to the weight of head etc. (see note 1), therefore the actual tension is, (8800 - 500), 8300 lbs. and the unit tensile stress is 4700 lbs. per sq. in.

Factor of safety $= \dfrac{60000}{4700 \times 2}$

$= 6.38$

Efficiency $= \frac{16000}{9400}$

$= 170\ \%$

Compression in AD or ED $= \frac{6080}{2.13}$, including 80 lbs. due to weight of head etc.

$= 2850$ lbs. per sq. in.

The length of Ag, L $= 6'$

$S = 16000 - 70\ \frac{L}{r}$

$= 16000 - 70 \times \frac{6 \times 12}{0.46}$

$= 5080$ lbs. per sq. in.

Efficiency, $\frac{5080}{2850 \times 2}$, $= 89\ \%$

Here $\frac{L}{r} = 156$ which shows that the member is a little too slender.

These factors of safety and efficiencies show that the members were designed to provide for the deterioration by rust and take up the stresses due to the dynamic forces of running current in swift rises and the collition of drifts etc. on the dam.

The channels when the dam is being raised are subject to flexure due to deposits of sands and the weight of the trestle proper, and to axial compression in direction of their lengths from the hoisting chain. We will investigate these in order.

Since the trestles are 4 ft. between centres, and by allowing 8 ft. of chain to each it is only necessary to wind in 4 ft. of this to properly bring the trestle to position and 6 trestles can be raised or lowered at one time. It may be assumed that each post, in being raised, must lift, for each foot of its length, a block of material 9 in. wide by 8 in. deep. Then $9 \times 8 \times 12 = 864$ cu. in. $= 0.5$ cu.ft. Net weight of sand in water is, $110 - 62.5$,

47.5 or say 5o lbs. per cu. ft. Weight of post and connections say 1o lbs per foot run. Hence total weight in post $= \frac{50}{2} + 10 = 35$ lbs. per foot run. The greatest length between supports = 16.5 !

Hence B.M. $= \frac{35 \times 16.5 \times 16.5}{8} = 1190$ lb - ft $= 14200$ lb. - in.

$$S. = \frac{Mc}{I} \qquad = \frac{14200 \times 2}{4.6} \qquad = 6170 \text{ lbs. per sq.}$$

inch for 4-in. 7.25-lb. channel.

Compressive stress due to raising is about 2oo lbs. per sq. in.

Total stress in raising = 58oo lbs. per sq. in.

Taking 75o lbs. , the weight of the trestle head, with floor, escape bar etc., with bottom of trestle resting on ground, and 99o lbs., one - half of the weight of the trestle proper and of the sand deposit along it, altogether as a single force of 174o lbs acting downward from the head of trestle which is just being raised from the sill, and also a force of 9oo lbs. acting down from any other point where the head of trestle is rigidly fastened to the hoisting chain, solve graphically and the stresses in both the chain and the trestles being raised are found as shown in fig. 3. The max. pull in chain is 55oo lbs. When the dam is being lowered the stresses produced thereby are less, therefore it is not necessary to take them into consideration here.

Allowable unit compressive stress $= 16000 - 70 \frac{16.5 \times 12}{1.46}$

$= 6500$ lbs. per sq. in.,

here $\frac{L}{r} = 135$

Efficiency, $\frac{6500}{6170}$, $= 105\%$ for downstream post

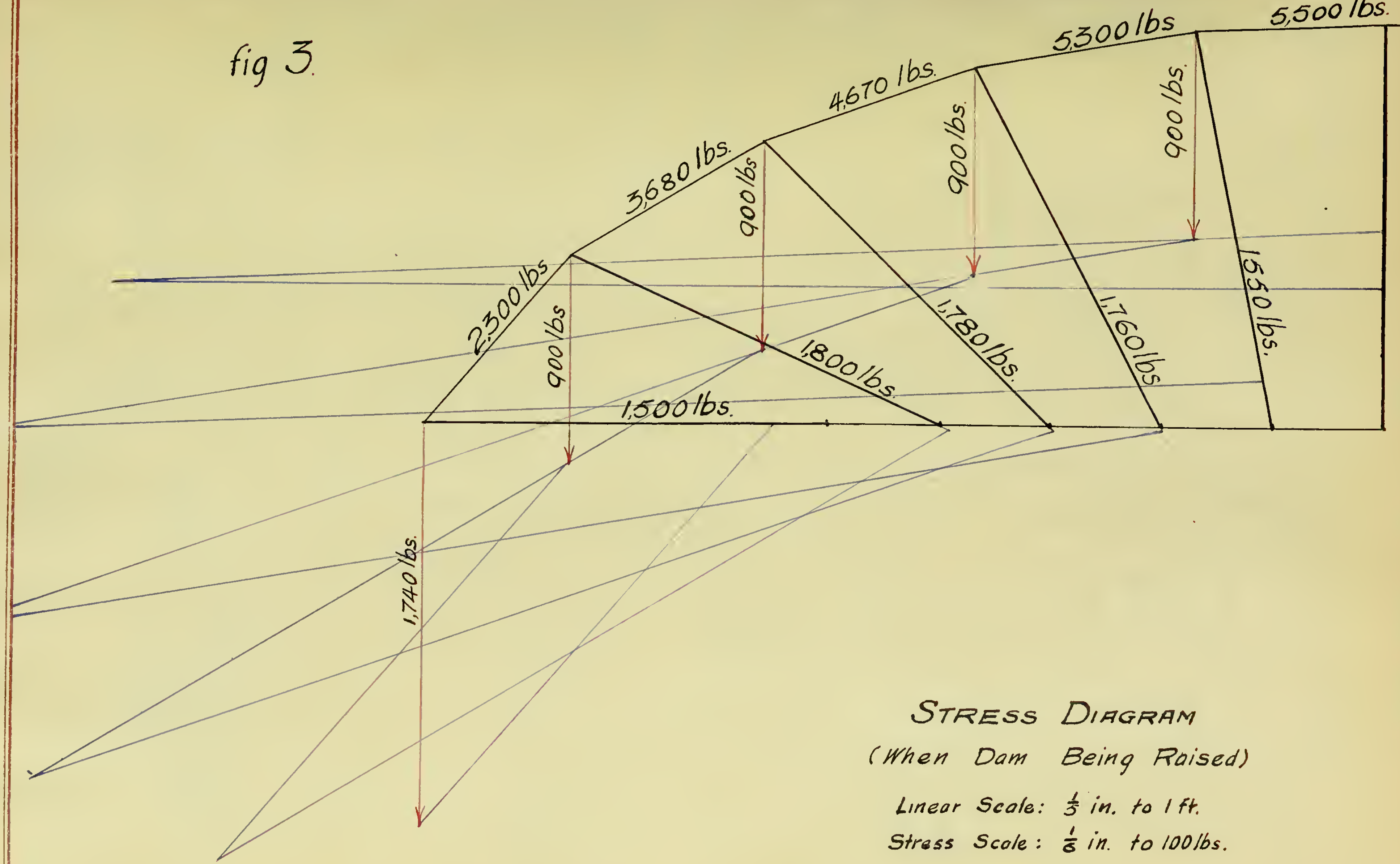
Efficiency for the upstream post $= \frac{7400}{5770} = 128\%$,

where $L = 15'$.

and B.M. = 12ooo lb - in.

Direct compressive stress = 57o lbs. per sq. in.

fig 3.



STRESS DIAGRAM

(When Dam Being Raised)

Linear Scale: $\frac{1}{3}$ in. to 1 ft.

Stress Scale: $\frac{1}{8}$ in. to 100 lbs.

Downstream journal box and pin, shoe plate and rivets:

These are always subject to compression. 1 plate (vertical) $5.5'' \times \frac{5}{8}'' \times 1\text{-}1''$ with 2.5" pin. The vertical component of the force of about 62oo lbs. due to water pressure and weight of trestle is about 55oo lbs. The bearing value of pin plate is 375oo lbs. Efficiency is, $\frac{37500}{5500 \times 2}$, about 29o %. The shearing value of $\frac{5}{8}$" rivets 8 in number under single shear is 36oo $\times$ 8 or 288oo lbs. Efficiency is about 262 %. Obviously the gusset plates and channels of the shoe, and pin are fairly strong. The horizontal component of 62oolbs. is about 288o lbs. resisted by the lower journal box which is embedded to about 1" in the trestle sill and held rigidly in place with 4 anchor bolts the diameter of which must not be less than $\frac{1}{2}$". The journal box itself is comparatively a solid substantial strong one which can stand the small force very safely.

Upstream journal box:

The upstream journal box with 2"pin, $5'' \times \frac{3}{4}''$ eye bar and $\frac{5}{8}$" rivets is subject to alternate stresses - compression and tension, the latter is much greater than the former.

Max. tension	=	about 83oo lbs.
Impact	=	also 83oo "
Total	=	166oo lbs.

Eye bar:made of medium steel.

Net section at pin hole, $(5 - 2) \times \frac{3}{4} = 2.25$ sq. in.

Actual tensile stress, $\frac{16600}{2.25}$, $= 7380$ lbs. per sq.in

Then Efficency, $\frac{16000}{7380}$, $= 217$ %

Pin:

Required section is, $\frac{16600}{12000}$, 1.28 sq. in.

Actual section is , $\pi \times 1^2$, 3.14 sq. in.

Efficiency is about 245% for shearing.

Required area for bearing , $\frac{16600}{24000}$, = 0.69 sq. in.

Actual area " " , $2 \times \frac{3}{4}$, = 1.5 sq. in.

Efficiency = 218 % .

Rivets: 8 in number under single shear.

Total sectional area , 8×0.3068 = 2. 45 sq. in.

Required " " $\frac{16600}{12000}$, = 1.38 " "

Efficiency for shearing = 177 %.

The up-stream journal boxes, embedded in the main sill, were made up of angle irons and plates held strongly by means of bolts to the main sill. They were made in a very substantial manner and comparatively stronger than the joint itself.

Sill:

The main sill, the purpose of which is to support the needles when the dam is up and protect the trestle when the dam is down, is made of good grade of white oak, and consists in section of two pieces 16" x 17" each, lying one upon the other and rabbeted so as to lap 3 inches. The various sections are halved together with a 2-foot lap and laid with broken joints. The sill is anchored down at intervals of 4 ft. to the masonry underneath with 1 $\frac{3}{4}$-in. rods 10 $\frac{1}{2}$ ft. long at the bottom of which is a heavy cast-iron disk, and is also anchored horizontally to the masonry up stream at intervals of 8 ft. by bolts passing thro the lower sill and by a strap passing thro the upper sill and over the masonry to the masonry tie strap. The trestle sill are 14 inches square and 12 feet long and are anchored by six 1-in. bolts set in the masonry with cement and lead.

As we have seen from the above investigation the transverse

and longitudinal forces acting on the trestle sills and the transverse force on the main sill is not very large, the bolts and sills figured out and investigated are found strong enough to resist them.

Weir trestle:

Pressure on top of weir trestle = 525 x 8 = 4200 lbs.

Tensile stress, lbs. per sq. in. $= \frac{4200 \times 7}{6.44} = 4600$

Compression stress, lbs. per sq. in. $= \frac{4200 \times 8.125}{5} = 6800$

One-half of which goes to A'D' and the other half to E'D'. Since the sections of the members of the weir are similar to and the stresses in them are much less than those of the pass, it is obvious that they are strong enough to stand the pressure of water, impact by drifts and strains due to operation and sand deposits, and it is not necessary to investigate them here.

Operating Mechanism, etc.

The raising and lowering of the trestles are done by a crab located on pier for weir, and on lock wall for pass. As the chain is wound in by two men it passes over a pocket wheel and drops thro. a hole in the masonry into the recess provided for pass trestles in pier. By means of a pawl dropping into the ratchet the rolling of the chain wheel may be stopped, and when this occurs the trestle is attached to the chain and the winding of the crab will move it as desired. When the first trestle (being the last lowered) is brought up the attendant standing on the wall grasps the floor, which rests on the chain, and raises it few inches. This raising depresses the opposite end into the point of pawl and lifts it out of the ratchet and thus allows the wheel to turn and releases the trestle from the chain. Thus the floor sections are raised and hooked to one another and the entire maneuver may be performed with-

out stopping the crab. The time taken to raise either pass or weir trestles is about forty minutes and that for lowering them is about twenty minutes. The maneuvers have all been fairly satisfactory so far.

Crab:

The height of handle above ground is about 3 ft. 3 in.; radius of circle described by the handle is 16 inches. The crab is geared in multiple purchase. Each man working at the handle has to exert about 35 lbs. to raise the trestle. The efficiency of the machine is about 35 per cent. The actual mechanical advantage is, $\frac{5500 \text{ lbs.}}{70 \text{ lbs.}}$, 80. Then velocity ratio must not be less than, $\frac{\text{mechanical advantage}}{\text{efficiency}}$ x 100, i.e. $\frac{80 \times 100}{35}$, 230.

Chain: open-link of elliptical form made of wrought iron.

According to British Admiralty rules, for open-link chains the greatest working load in tons is $6d^2$ or 3.85 tons per sq. in. of section, where d is the diameter of the iron forming the chain. In this case the section of the chain must not be less than,

$\frac{5500}{3.85 \times 2240}$, 0.64 sq. in. or the diameter of the iron bar forming the link must not be less than $\frac{5}{8}$".

Substructure:

The substructure is of concrete and sandstone masonry. In the pass it is 22 ft. at the coping. The pass masonry averages about 12 ft. in height. Immediately overlying the bed rock is placed a layer of concrete varying in thickness, but averaging about 4 ft. On this bed of concrete and near its upstream and downstream edges are built two parallel masonry walls. Toward the upstream side the masonry is raised. The comparatively weak part of the substructure is that near the pier. The downstream masonry wall is 16 ft. high with a layer of concrete 5 ft. thick, and upstream masonry wall is 11 ft. high with about 2 ft. concrete.

$p_1 = 13 \times 62.5 = 813$

$p_2 = 26 \times 62.5 = \underline{1626}$

$2439, \quad \frac{2439}{2} = 1220$ lbs.

$P_u = 13 \times 1220 = 16000$ lbs. for 1 ft. pass.

$= 64000$ lbs. from centre to centre of trestles.

$X_1 = \frac{(813 + 2 \times 1626)}{2439} \times \frac{13}{3} = 7.2'$

$p_3 = 2.5 \times 62.5 = 156$ lbs.

$p_4 = 23.5 \times 62.5 = \underline{1470}$ lbs.

1626 lbs. , $\frac{1626}{2} = 813$ lbs

$P_d = 21 \times 813 = 17000$ lbs. for 1 ft. pass.

$X_2 = \frac{(156 + 2940)}{1626} \times \frac{21}{3} = 13.3'$

Weight of concret or rock = 140 lbs per cu. ft.

less weight of water = $\underline{62.5}$

77.5 " " " "

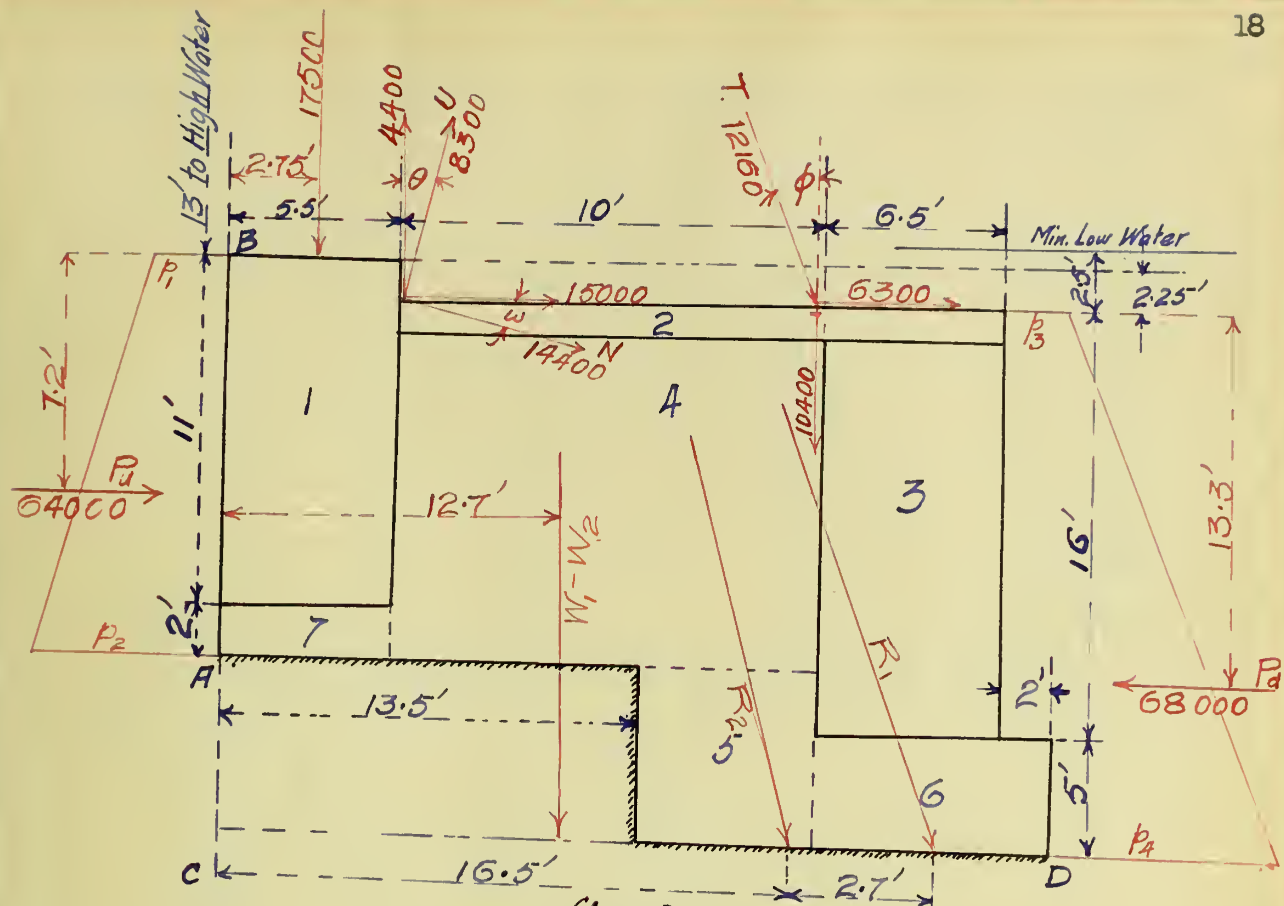


fig. 4.

Substructure.

Cos. Ø = 0.855 Sin. Ø = 0.519

Cos. w = 0.965 Sin. w = 0.261

Cos. θ = 0.990 Sin. θ = 0.139

1,2 and 3 are of sandstone.

4,5,6 and 7 are of concrete in one mass.

N = Pressure from needles against the sill.

T = Thrust from down-stream leg of trestle.

U = Upward pull from up-stream leg of trestle.

W_1 = 108000 lbs., weight of masonry calculated with loss of weight by immersion.

W_2 = 218500 lbs., weight of masonry.

R_1 = 109200 lbs., resultant of W_1 and all external forces.

R_2 = 220000 lbs., resultant of W_2 and all external forces.

Assuming N to act upon the same axis as T. and U.

No.	Area in sq. ft.	Distance from A.	Moment
1	11.0 x 5.50 = 60.5	2.75'	165.0
2	1.5 x 16.5 = 25.0	13.75	344.0
3	6.5 x 14.5 = 94.2	18.75	1769.0
4	10.0 x 9.3 = 93.0	10.50	975.0
5	2.0 x 10.5 = 21.0	14.50	304.0
6	8.5 x 5.0 = 42.5	19.75	842.0
7	5.5 x 2.0 = 11.0	2.75	30.0
Total	= 348.2		4429.0

Therfore centre of gravity is, $\frac{4429}{348.2}$, 12.7' from A.

Σ V about A.

1c8000 x 12.7 = + 1370000

10400 x 15.5 = + 161000

17500 x 2.75 = + 48000

+ 135900 + 1579000

— 4400 x 5.5 — 24000

+ 131500 + 1555000

Therefore *R.* of ΣV is, $\frac{1555000}{131500}$, 12.0' from A. *R* ÷ *Resultant.*

ΣH about B:

64000 x 7.20 = + 461000

15000 x 2.25 = + 39000

6300 x 2.25 = + 14000

+ 85300 + 514000

- 68000 x 15.50 = - 1054000

+ 17300 - 540000

Therefore *R.* of ΣH is, $\frac{-540000}{+17300}$,-31.2' from B.

ΣM about C:

ΣV x 12.0 = 1580000

ΣH x (31.2 + 23.3) = 942000

Total $=$ 2522000

Therefore the resultant is, $\frac{2522000}{131500}$, 19.2' from C.

In the above case it was assumed that water found its way under and around the foundation of the walls, and that it decreased the pressure of the dam on the foundation, and consequently decreased the stability of the walls. The effective weight of the submerged portion of the dam would be thereby decreaed 62.5 lbs. per cu. ft. However, it is not likely that water can get into the concrete foundation adhesively set on the rock bed, and hence the assumed effect of buoyance may be excessive.

Assuming full value of weight of masonry W will be equal to 195000 lbs.

ΣV about A.

195000 x 12.7	=	2480000
10400 x 15.5	=	161000
17500 x 2.75	=	48000
+ 222900		+2689000
- 4400 x 5.5	=	- 24000
+ 218500		+2665000

Therfore resultant of ΣV is, $\frac{2665000}{218500}$, 12.2' from A.

ΣM about C.

ΣV x 12.2	=	2665000
ΣH x (31.2 + 23.3)	=	942000
		3607000

Hence the final resultant pierces the base in a point,

$\frac{3607000}{218500}$, 16.5 ft. from C.

Taking the width of base as 24 ft., the Factor of Safety against overturning is, $\frac{(24 - 12.2)}{(16.5-12.2)}$, 2.75.

In the above computation the walls were taking as verical, but actually they broaden out at the base and the base of foundation is about 27 ft. wide. Hence the resultant may possibly lie within the " middle third " of the base and there be no tension in the masonry. Nevertheless to find the stability against crushing we will take 24 ft. as the width of base.

Since the point of application of the final resultant is found to be 7.5 ft. from D, the normal pressure on the section will act at this point and the part of the width of base, on which the normal pressure is distributed, will be 22.5 ft. Assuming that the upstream edge will not take tensile strain, the max. pressure on the downstream edge will be, $\frac{218500 \times 2}{22.5 \times 4}$, 4856 lbs., or 2.5 tons per sq. ft. say. The average safe crushing strength of concrete of proportion 1:4:8 (approx.-) is about 30 tons per sq. ft. and that of squared sandstone with ordinary mortar is about 15 tons per sq. ft. Hence the substructure is very strong against crushing.

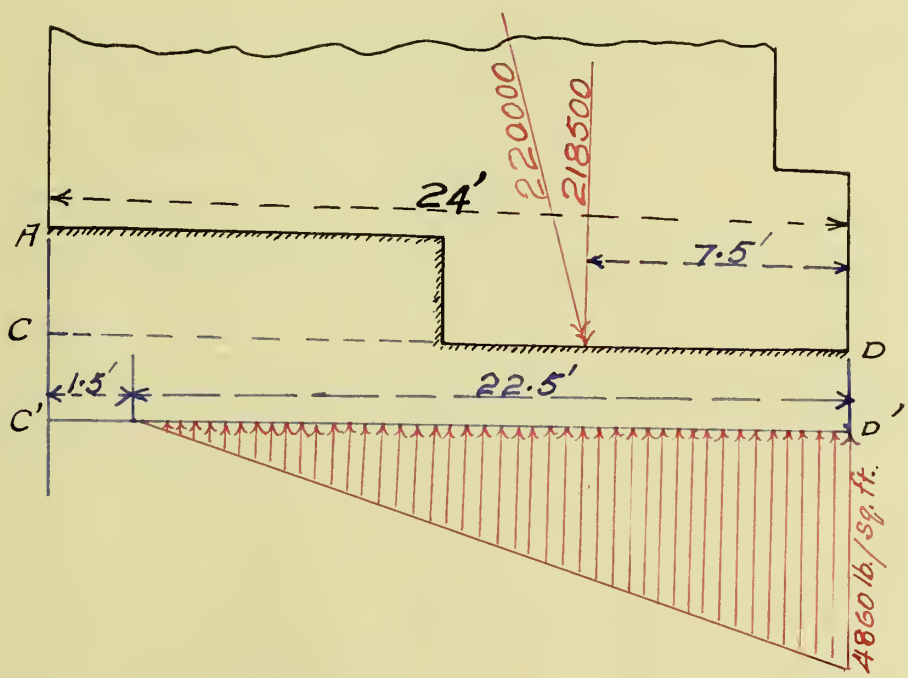


fig. 5.

CONCLUSION.

The sediment in many rivers may decide the character of the dam. The needle dam is favorable for a condition of much sediment. If the deposit is not too great, the parts can be loosened and raised; if deep, scraping or shoveling is at first resorted to, and afterwards the erected portion utilized to deflect a current that will wash away the remaining deposit.

The defects of the needle type as compared with some other types of dams such as the bear-trap, drum-weir, Chanoine wickets etc. are the leakage, the difficulty of handling the heavy needles by one man and the labor and time in operating the trestles, but the first two principal objections have been overcome in the dam described by the use of needles handled by machinery, and of such dimensions as to make practically a tight wall. For situations where time and labor are not prime factors, the Poirée frame fitted with needles is satisfactory for movable dam. The needle type admits of structure of any length, and leaves a clear open river when dam is down. It possesses three merits which will commend themselves to thoughtful and careful men:

(1). Their adaptation for any length;

(2). Their immunity from serious derangement by a deposit of sediment; and

(3). Their facility with which damaged trestles and needles can be replaced.

Note 1

weight:trestle head and fittings.

Floor....................	112	lbs.
Head and frame.........	442	"
1 wheel and 8' chain.....	143	"
Total....	700	" say
Main members and braces..	430	"
Grand total........	1130	lbs. say